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MAGNETOS

FOR AUTOMOBILISTS

MAGNETOS

FOR AUTOMOBILISTS

HOW MADE AND HOW USED

A Handbook of

PRACTICAL INSTRUCTION IN THE MANUFACTURE AND ADAPTATION OF THE MAGNETO TO THE NEEDS OF THE MOTORIST

BY

elimo omeo

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AUTHOR OF "THE DYNAMO," "IGNITION DEVICES," ETC.

Capio Lumen

WITH THIRTY-FIVE ILLUSTRATIONS

LONDON
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1907

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PREFACE

In view of the present growing popularity of the Magneto among all classes of motorists, the Author feels that no apology is needed for putting before the public such simple explanations as will enable the tyro to comprehend and apply the principles on which this system of ignition is built up.

He has endeavoured, therefore, so far as is permissible within the limits of this slight work, to give a brief outline of the history, construction, and function of the magneto as generally used by motorists, in the hope that an amateur provided with a machine of this type may not be at a loss should slight repairs or adjustments be required when the services of an electrical expert are not obtainable, and may even, given the requisite tools, skill, and patience, be able, in an emergency, to make the magneto for himself.

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Although widely different methods of obtaining the electrical current are adopted in the two contrasting systems—the principle in the one being "chemical changes," and in the other the movement of conductors within the field of force—yet it must be recognised that the sole *raison d'être* of each is the generation of this necessary current. Either system can, therefore, be easily substituted for the other, without any great change in the wiring, fitting, etc., of accompanying machinery.

But the favour that the magneto system has found with the motoring public is not surprising, when the many advantages of that system in avoiding the trouble and expense entailed by constantly re-charging accumulators, as well as the attendant danger of spilt acid and burnt-out coils, are considered.

S. R. BOTTONE.

WALLINGTON,
September, 1907.

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MAGNETOS FOR AUTOMOBILISTS

CHAPTER I

THE MAGNETO: ITS HISTORY AND THEORY

Importance of ignition—Faraday's discovery—Medical magneto—Breguet's igniter—Siemens' Armature—Methods of cutting lines of force—Commutator—"Lines of force" and "field of force"—Theory of the Magneto—Essential parts of the Magneto.

1. **Importance of Ignition.**—Of all the accessories which conduce to the perfection of action in the motor-car, and in the chauffeur to the feeling of security while travelling, there is perhaps none, with the exception only of the engine itself, that plays so important a part as the means adopted for ignition. Not only must it be certain, but it must be also perfectly under control; so that the explosions should not only take place without fail, but also at the exact time when required. In another place * we have treated pretty fully

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* See "Ignition Devices for Gas and Petrol Motors." Guilbert Pitman.

on the use of the coil and accumulator for this particular purpose. Here we propose showing how the magneto machine (and its congeners, the dynamo coil, the Eisemann, etc.), are constructed, along with the directions for use, suitability for special purposes, defects and their remedies. In order that the reader may form an intelligent idea of the mode in which these machines act, it will be necessary for us to preface our papers with a few remarks on the origin of the magneto, and the improvements which have been introduced therein in obedience to the demands made for special purposes.

2. Faraday's Discovery.—In 1831 Faraday showed that the approach or recession of a conductor to the poles of a magnet sets up a current of electricity in that conductor at right angles to the direction of its own motion. From an old print in our possession we gather that the means adopted for showing this result was somewhat similar to that illustrated in our Fig. 1, in which A represents a rod of soft iron wrapped round with a few coils of insulated copper wire, C, one end of this latter being brought into proximity with a little button or disc, B, not however actually touching it. If now the iron rod A be suddenly brought into contact with one of the poles of the magnet M, or as suddenly removed, a brilliant spark will be seen to pass between the point of the wire and the button or disc, due to the sudden flow of current elicited in the coil of wire by its approach to, or recession from, the magnet. The reader must particularly notice that this result is only obtained when one or other of these two movements is taking place; and that the more powerful the magnet, the greater the number of coils, and the more sudden the motion, the more energetic the spark thus obtained.

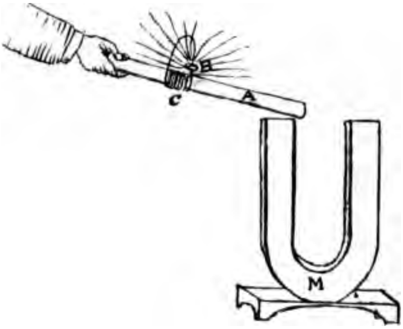

FIG. 1.

3. **Medical Magneto.**—As soon as the results of Faraday's experiments were made known, numerous applications were devised for utilising the current thus obtainable, and the well-known medical magneto, of which we present an illustration at Fig. 2, was among the earliest practical

uses to which the discovery was put. We are, however, more concerned with the application of such machines to the purposes of ignition than to any other, and will consequently pass on to notice a form of igniter which embodies many of the good points existing in our present instruments.

FIG. 2.

4. **Breguet's Igniter.**—The one to which we refer was devised by Mons. Breguet, and is represented at our Fig. 3. Here we have a compound magnet, AA, built up of three or four thinner ones screwed together. The ends of this are made smaller than the rest, and rounded off so that two bobbins, BB′, may be fixed upon them, the poles of the magnets passing through, and just projecting on the farther side. The keeper

(or armature) C is mounted on a bent lever, D,

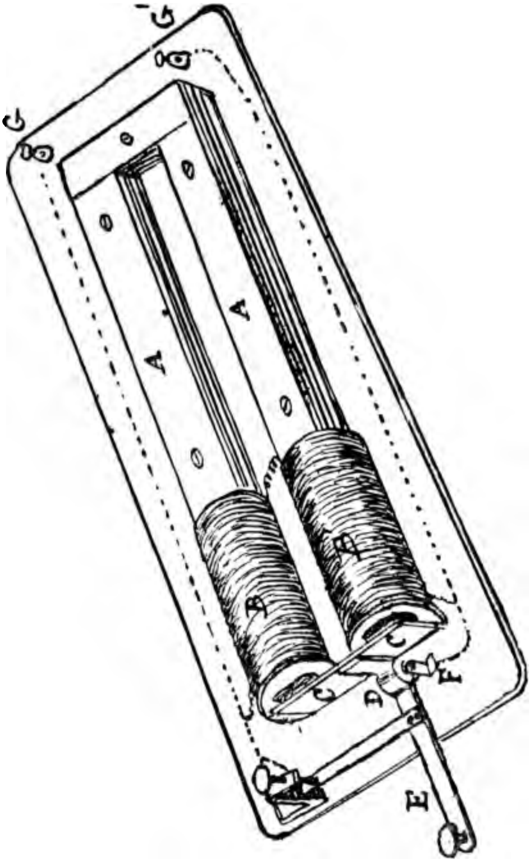

Fig. 3.

turning on pivots, one of which is seen at F. This is so arranged that when the handle E is pressed down the keeper is suddenly withdrawn from contact with the poles. One end of the wire round B is fastened to a corresponding end of that on B′, the other two ends from the bobbins being taken underneath the board, and then connected to the binding screws GG′. The dotted lines show the course of the wires. If now a blow be struck on the handle E the keeper is immediately separated from the poles, and as a result an instantaneous current passes round the bobbins and between the binding screws GG′. If a fuse be placed between these it will at once be ignited, and by placing the finger and thumb on them the shock may be distinctly felt.

5. Siemens' Armature.—But ingenious and simple as this arrangement is it does not lend itself conveniently to application in automobilists' work. For this purpose a modification of the well-known Siemens' armature is the one most usually employed. We will, therefore, next consider the construction of a simple instrument of this type. We will begin by studying the armature, of which we give an illustration in its wound condition at Fig. 4. Here we have a cylinder of soft iron, usually built up of laminations, of which the length is about three times the diameter; on two sides this is deeply channelled out, so as to present the section of an "H-girder." This armature is supported at its two ends by a spindle passing through it, which spindle rests on suitable bearings, where at one end is arranged a pulley, or other convenient means of imparting motion to the armature, and at the other a device known as a commutator, or collector, by means of which the electricity set up in the wire (with which the channels in the armature are wound) can be collected and sent to the outer circuit, where they are to be utilised. Bridging over the armature is placed a compound magnet (Fig. 5), usually fitted with pole-pieces, as indicated by transverse lines. These magnets serve to produce "a field of force" across the space occupied by the armature, and it is just by cutting the "lines of force," which pervade this space, that the flow of current is evoked.

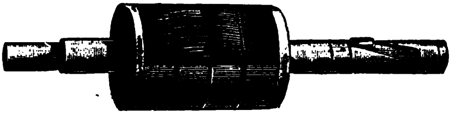

FIG. 4.

6. Methods of cutting Lines of Force.—It is indifferent to the success of this operation whether the armature be moved or whether a light iron shield be interposed between the poles of the magnet and the armature, and, therefore, both methods have been adopted by different makers. Of course, in the latter case the shield itself is moved while the armature remains stationary, so that the armature is alternately exposed to, or shielded from, the inductive effects of the lines of force.

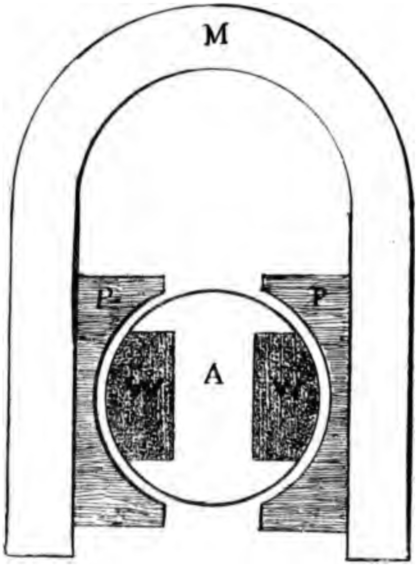

FIG. 5.

A, the armature; W, the wires or conductors lying in the channel; M, the magnet; P, the pole-pieces.

7. Commutator.—We may point out here that if the two ends of the wire wound round the armature are tested during one entire revolution of an unshielded armature, the direction of current flowing will be found to change *twice* with each complete revolution. This, usually speaking, is of no consequence for ignition purposes; but when it is desired that the current should go always in one direction, this object can be easily attained by connecting the two ends of the wire to two semicircular metal cheeks, supported on an insulating sleeve fitted on the spindle, usually at the end opposite to that at which the pulley is affixed. This arrangement of collector, as it *commutes* the direction of the currents which are alternately on the one side and the other, to one uniform direction, is known as a "commutator," and this requires two "brushes" which, sweeping against the cheeks of the commutator, allow the current to be collected and sent where required.

8. "Lines of Force" and "Field of Force." —It will be well for the student to make a simple experiment in order to form a conception of what is meant by "lines of force" and "field of force." By "lines of force" are meant certain imaginary lines in which magnetism is exerting its power; by "field," is meant the entire space where these lines are passing or where the force is being exerted. Let the reader procure an ordinary horseshoe magnet, and lay it on a flat table, cover it with a sheet of writing-paper, and sift over it, from a height, a pinch or two of very fine iron filings. He will see that the filings will arrange themselves in a certain definite order, crowding pretty closely together in the space between the poles of the said magnet, and becoming more diffused into curved lines as they recede from those points. If the paper be gently tapped while the sifting operation is being performed, the outlines of these "lines" will be more distinctly visible, and if the paper has been previously dipped in melted paraffin wax and allowed to get quite cold before sifting on the filings, it will be

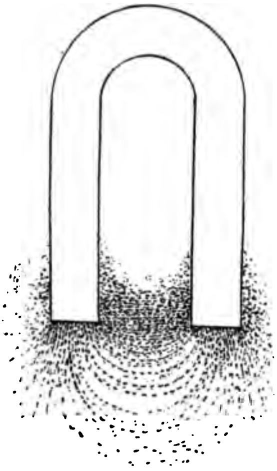

FIG. 6.

possible, by cautiously removing the paper after having scattered thereon the said filings, to get a permanent record of the positions of these lines of force by gently warming the paper over a spirit lamp, when the wax will melt and retain the filings in the position they had taken up. Our Fig. 6 will give a general idea of the arrangement of such filings when scattered over the poles of a parallel-limbed horseshoe magnet. The reader must bear in mind that such a representation shows the lines of force in *one plane only*; while, as a matter of fact, these lines surround the magnet in every direction, becoming, however, feebler as they are more distant from the poles.

9. Theory of the Magneto.—We may now recapitulate the main facts that we have learnt before proceeding to explain the construction of the different forms of magnetos now actually employed. In the first place, we have to form a conception that every magnet is surrounded by lines of force, radiating from its two poles, which lines form catenary curves which become more open and more diffused as the distance from the poles becomes greater. Secondly, that any conductor moved so as to cut these lines of force is affected by them; so that a current is set up in the conductor at right angles to the direction of motion. Thirdly, that the intensity of the current thus elicited is dependent upon the number of lines cut in a given time, or, what amounts to the same thing, to the strength of the magnet and to the rapidity of the motion. Fourthly, that the most convenient form on which the conductor or conductors can be arranged, in order to maintain a continuous motion, is that of a cylindrical body. Fifthly, that this cylindrical armature along which the conductor or conductors (wires) are wound longitudinally, should preferably be of soft iron, as this metal has the property of drawing towards itself the lines of force emanating from the magnet, and consequently of concentrating their effect upon the space occupied by the conductors. Sixthly, that it is the sudden change of magnetic condition set up by the lines of force on the conductors that gives rise to the flow of current; hence it is indifferent whether this change is brought about by alternately exposing the conductors to the influence of these lines, and then withdrawing them from it, as obtains when the armature is rotated, or whether the same result is brought about by alternately shielding and exposing the armature to the effects of the said lines, by causing a soft iron shield (which shield concentrates the lines of force upon *itself*) to rotate between the poles of the magnet and the armature, which in this case is held stationary. Seventhly, that the current thus set up is alternate in direction; and, in order to render such a current available in one direction only, it is necessary to make use of a "commutator."

10. Essential Parts of the Magneto.—In order that the learner may form a clear idea of the relative positions of the armature and the magnet or magnets in a magneto igniter, we present the reader at Fig. 7 with an illustration of the essential parts, in which we represent at A, the armature as lying longitudinally between the pole pieces of a compound magnet M, the jaws of which are bored out so as to permit the armature to rotate in close proximity to them; the rotation being imparted in this case by means of a handle, H, driving a cog-wheel, W, which in its turn engages in the teeth of a smaller cog-wheel, and

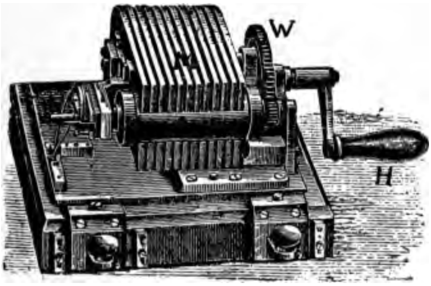

FIG. 7.

thus insures great rapidity of motion. The reader will readily understand that in the actual machine the motion will be imparted by some moving part of the engine or the car, not by a handle; and likewise, that the bearings and terminals, by means of which the current is conducted to the spot at which it is desired to produce the spark, are for the sake of compactness affixed to and form part of the magnets themselves. By this means it is possible to arrange the *timing* apparatus, which is of the highest importance for the successful working of the igniter (on the body of the magneto itself), without unduly increasing its bulk.

CHAPTER II

COMPONENT PARTS OF THE MAGNETO

Material and form of magnets—Size of magnets—Compound magnets—Hints on fitting magnets—Clearance between armature and pole-pieces—Armature with or without shield—Contact of armature with machine—Fitting spindle to armature—Winding armature—Pattern of bearings—Insulation of front bearing—Closed and open circuits—Contact breaker actuated by two-to-one gear—Breaking contact—Making contact—Alternative contact-breaker or plug.

11. **Material and Form of Magnets.**—The first requirements for making up a magneto are:—1, the magnets; 2, the pole-pieces; 3, the bearings; 4, the armature. Beginning by the magnets, these are made of the best shear steel, such as that produced at the Allevard works, though, provided the steel be capable of being forged, and afterwards being made dead hard, the particular brand is of no great moment. The presence of *manganese* is, however, to be avoided, as such steel is practically incapable of due magnetisation; on the other hand, the presence of a small percentage of *tungsten* seems to favour the retention

of a high degree of magnetism. The usual form given to the magnets is that of a horse-shoe with parallel limbs, of which the width is usually from two to three times that of the thickness. Single magnets are not generally used. It is customary to build up each magnet of the set (of which there are usually three), by fitting two, or even three, magnets straddling one over the other, each additional magnet being a trifle wider in expanse between the limbs than the one within it.

12. Size of Magnets. — The sizes usually adopted for these magnets run about 2¼ in. or 2½ in. in expanse between the limb, 6 in. in height, and 4¾ in. in width. In the smaller magnetos, such as are used for motor-cycles and similar light automobiles, somewhat lesser dimensions will be found to give sufficient strength; but for large cars in which more space is available, it is wise to use the larger sizes, though it is not essential that the magnets should be of any extraordinary size, provided the combination (compound magnet) have sufficient magnetism to lift a weight of not less than thirty pounds attached to an iron plate put across their poles. In the larger magnetos the lifting power may rise even to forty-five pounds.

13. Compound Magnets.—At Figs. 8 and 8A we give illustrations in section and elevation (with dimensions) of a compound magnet attached to its pole-pieces, each single magnet (of which there are three) being built up of two laminations,

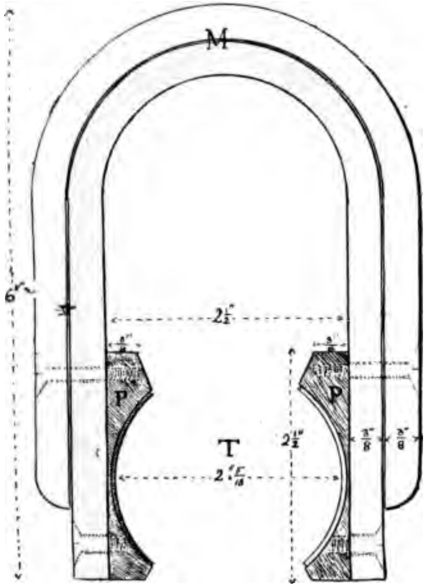

FIG. 8.—Sectional Front Elevation.
M, Compound magnet; **P**, Soft-iron pole-pieces; **T**, Tunnel for armature.

forged so as to fit accurately, the larger over the smaller, holes being drilled through both at the points indicated, and countersunk on their outsides to admit of the insertion of the flat-headed screws, which serve to fasten the individual magnets not only to each other, but also to the two soft iron blocks which constitute the pole-pieces. It must be remembered that the dimensions given

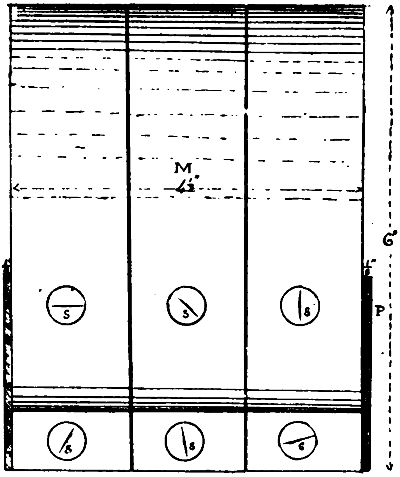

Fig. 8a.—Side Elevation.
M, Compound magnet; P, Pole-pieces, salient portions; S, Screws uniting magnets and poles.

are those suitable for a medium-size magneto; but the operator must be prepared to find in trade great departures both in the sizes and patterns of the different magnetos, according to the taste and requirements of the manufacturers. Thus, for instance, he will find in some cases the individual laminæ which constitute each single magnet to be two, or even three in number, very rarely one only, and still more rarely exceeding three. In like manner in very small magnetos, two compound magnets only may be employed to embrace the pole-pieces, the usual number, however, being three.

14. Hints on Fitting Magnets.—In any case, it must be borne in mind that all work, in the way of drilling holes, fitting, cleaning up, or otherwise working upon the steel, of which the magnets are constructed, must be executed *before the steel is hardened and previous to magnetisation,* because it would be practically impossible to perform any such work after the steel had been hardened, and, even if it were possible, it would be greatly to the detriment of the magnetism imparted to them. For this reason, having decided upon the size of the armature to be inserted, the operator will do well to fit the pole-pieces to the magnets as the next operation, leaving the hardening and the magnetisation of the steel until all fitting is completed. In order to facilitate the operation of putting the magnets together without risk of mistakes as to polarity, the operator will do well at this point to mark all the constituent magnets on one and the same side with a letter N, by the aid of a steel letter-punch, remembering when he comes to the operation of magnetising the individual laminæ so to act as to produce north poles at the extremities thus marked.

15. Clearance between Armature and Pole-pieces.—In the accompanying figures, which illustrate a machine in which a movable shield is made to oscillate between the pole-pieces and the armature, the latter being immovable, the dimensions given for the armature are such as to admit of the insertion and motion of the said shield between the two. It must be noted that, in order that the full power of the magnet may be exerted upon the wiring of the armature when the shield is shifted, the tunnel must be bored out so as to leave the very minutest possible clearance between the two; since, as magnetic forces act with a strength which is inversely proportional to the square of their distances, a very trifling increase in clearance makes a very great difference in electrical output. For this reason, the clearance given between an armature (or its shield) and the pole-pieces does not usually exceed the thickness of a sheet of writing-paper, or, say, $\frac{1}{100}$ in.

16. Armature with or without Shield.—Where a shield is used, as in the low-tension Simms-Bosch and machines of similar type, it usually takes the form shown in Fig. 9, where the dimensions are given. But, where no shield

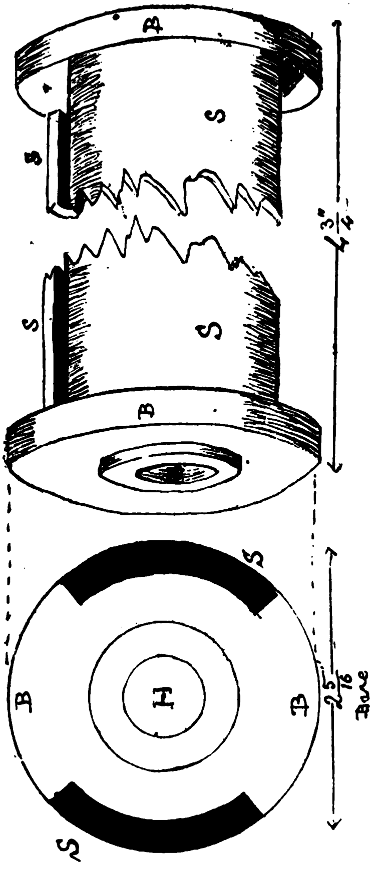

FIG. 9.

SS, The two iron segments forming the "shield"; B B, The circular brass heads to which the segments are attached laterally; H, The central spindle hole, ⅝ in. diameter.

is used, the relative diameter of the armature is shown at Fig. 10. The armature itself is usually made of good soft iron, and may either be drop-forged, of the rough dimensions and shape, or else cast and annealed, the former being preferable.

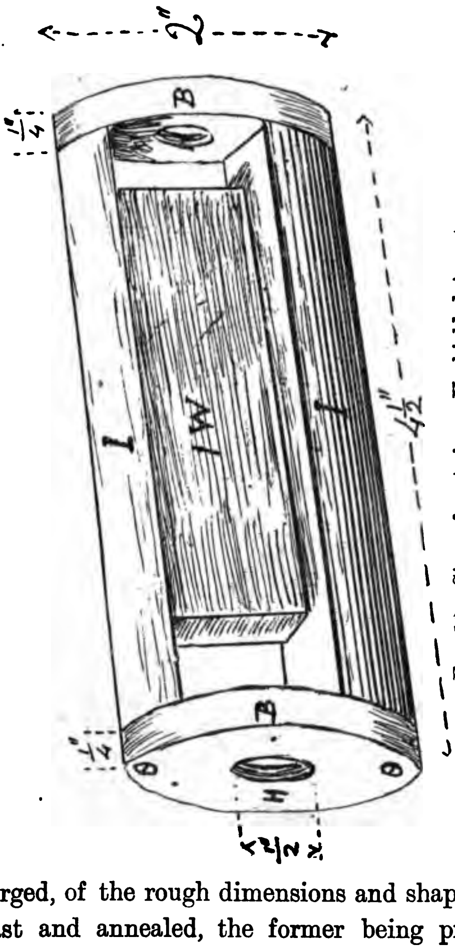

FIG. 10.—Sizes of parts in an Unshielded Armature.
I I, The iron cheeks of armature; I W, The central iron web; H H, Holes for spindle; B B, The brass heads or caps.

In either case it must be accurately fitted, and finished up on the lathe. If a shield be used, this, which embraces the armature, should have a thickness of $\frac{1}{4}$ in., and, if it were continued to form a perfect cylinder round the armature, would have a diameter of $2\frac{5}{16}$ in., less the clearance that we have stated above. But it must be borne in mind that the shield is not continuous, but consists of two segments, each constituting very nearly one-quarter of an entire circle, being fixed at opposite points in the circumference to two circular brass heads of the same diameter—namely, very nearly $2\frac{5}{18}$ in. These brass heads are usually cast in $\frac{1}{4}$ in. brass, with cylindrical extensions. When an unshielded armature is used, its diameter may be reduced to 2 in., the tunnel in the pole-pieces being bored out to a correspondingly smaller diameter, plus the clearance.

17. Contact of Armature with Machine.—Whether we decide finally to use our armature with a shield or without, there is one point that will have to be borne in mind, and that is, that while the starting-end of the armature winding must be placed in electrical contact with the iron body of the armature (and consequently with the whole mass of the machine) by being caught under the head of a cheese-headed screw inserted therein, the termination thereof must be brought out, carefully insulated (through the spindle, which, for this reason, must be, not only hollow, but carefully bushed internally with ebonite, or some other similar good insulator).

18. Fitting Spindle to Armature.—We will, therefore, now pass to the consideration of the means usually adopted to fasten the heads and the two extremities of the spindle to the core of the armature. This we have partially illustrated in our last figure (Fig. 10), as being effected by means of screws passing through the brass heads into the iron of the armature; but, as it is essential that the armature should be absolutely central in its tunnel (or between the two cheeks of the shield), with the minutest possible clearance, it is also necessary that its attachment to the two heads should be rigid and immovable. To meet this requirement, on the inner faces of the brass heads, at a distance of about $\frac{1}{8}$ in. from the circumference, are cut, whilst it is rotating on the lathe, two chamfers, one on each, of about $\frac{1}{16}$ in. width, and of similar depth, and on the heads of the armature core itself are produced two corresponding ridges that fit exactly into the said chamfers, and thus ensure perfect centricity and rigidity. The back spindle (by which we understand the one to which action would be imparted by means of a dog clutch or cardan joint) will consist in a round steel rod of about 2 in. in length and $\frac{3}{4}$ in. in diameter, one end of which has a shoulder turned down to enable it to fit into a $\frac{1}{2}$ in. hole made in the centre of the corresponding armature head, into which it is sweated and burred over. The other end of the spindle consists in a steel tube, about $\frac{1}{2}$ in. in diameter, $2\frac{1}{4}$ in. in length, with a shell of $\frac{1}{8}$ in. thickness. One end of this should be threaded for a length of about $\frac{1}{4}$ in., to enter in a hole in the centre of the front armature head, and then burred over, to render it absolutely immovable. This tube, forming the front shaft, is now to be fitted with an ebonite bushing, reaching from end to end internally, and projecting at the outer extremity for about $\frac{1}{8}$ in. beyond the front of the spindle, to which it is to be firmly attached by means of a little shellac varnish applied to the ebonite externally before it is finally driven in. When this has been done, a $\frac{1}{8}$ in. hole is put through the centre of the ebonite bushing from end to end, and into this will be afterwards inserted a copper rod, $\frac{1}{8}$ in. in diameter, bearing at one end a mushroom-shaped brass cap, of the same diameter as the ebonite bushing; and at the other, reaching through the hole in the front armature head, where, when required, it can be attached to the terminating wire of the armature winding.

Fig. 11 will give a clear idea of the mode in which the front spindle is bushed and connected to the armature windings; and this mode of connection will hold good whether the armature itself be rotated or oscillated, or whether it remains motionless while a revolving or oscillating shield (embracing the armature) be employed to vary the intensity of the field of force.

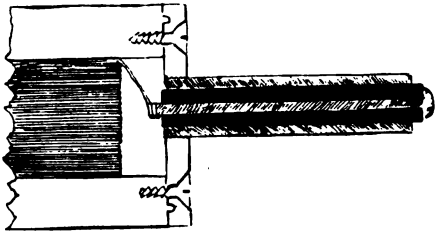

FIG. 11.—Section of front spindle, showing connection of armature wiring to the insulated central rod and stud.

19. Winding Armature.—To wind the armature, we shall require from ½lb. to ¾lb. of No. 26 double cotton-covered wire; but before proceeding to the winding, the web of the armature, as also the inner cheek of the armature channel, should be carefully "dressed" with silk ribbon dipped in shellac varnish, so as to ensure adhesion and to prevent the wire, which will be afterwards laid on, from accidentally coming into contact with the metal of the armature itself.

These being dry, the next operation is to insert a small screw in one of the inside faces at the back end of the armature; and, under the head of this screw, is caught a little loop of the said wire, the end of which has been previously bared, to ensure good metallic contact. This being done, the wire is wound as evenly as possible round the web, longitudinally on the channel, care being taken that each succeeding coil lies close to its neighbour—so close, in fact, that the wire of the succeeding layer shall not sink in between any space left in the subjacent layer. Each complete layer, as it is wound on, should receive a coat of good shellac varnish, and the winding continued in this manner with one length of wire until the channel is nearly filled up, when a transverse binder of phosphor bronze wire should be bound round the armature in a little channel previously turned therein, with the end of preventing the armature winding from rising from its place by centrifugal tendency. It is usual and advisable to put a little strip of thin mica over the wire at the place where the binding wire crosses it; and, finally, to fasten down the binding wire by means of a drop of solder applied with a hot bit. The free end of the armature winding is now bared and carefully soldered to the projecting extremity of the $\frac{1}{8}$ in. copper rod which extends from the brass cap at the end of the front bearing right through the bushing of the front spindle; and, to avoid any accidental short-circuiting which might arise from any unobserved contact between the armature wires and the inner cheek of the front brass head, to "dress" the inner surface of this said brass head with a piece of jean dipped in shellac varnish and thus fastened thereto. We have purposely left the exact amount of wire to be employed somewhat vague, because it will depend very largely upon the size of the armature and the character of the spark it is desired to obtain. But, in the case under consideration, of which we have given dimensions, from 8 oz. to 10 oz. will generally be found sufficient. The gauge of the wire is also of importance. Coarse wire gives a fatter spark than fine wire; but, in order to get as high a tension with a coarse wire, say, No. 22 or No. 24, as with the finer previously mentioned, the armature (and consequently the field magnets) must be larger in proportion, to admit of a larger quantity of wire being wound on.

20. Pattern of Bearings.—The bearings next demand our attention. These take varied forms in the hands of different makers, in accordance with their different requirements. A very common pattern is that shown at Fig. 12, in which we have a gunmetal plate about $\frac{1}{4}$ in. thick, of the same width as the base of the magneto below, but becoming somewhat narrower as it approaches the bend of the magnets. On this plate is cast at the same time a conical box about 1 in. deep, and a nozzle or collar 1 in. in diameter, which will

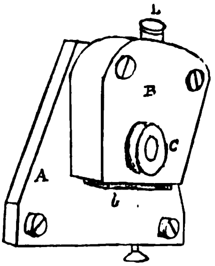

FIG. 12.—Elevation of back bearing.
A, Gunmetal plate; B, Recessed box; C, The nozzle or bearing proper; *b*, Bottom cover; L, Lubrication cap.

afterwards be bored to take the armature spindle. The conical box is cast hollow (except where the nozzle or collar traverses it), and herein are arranged the ball bearings (if such be used), the means of lubrication, such as "wick," "ring," or Stauffer's, etc., at the option of the maker. In many cases the bearing-box is furnished with a well-fitting cover *b*, held in place by two lateral bowed springs (see Fig. 13, *s s*), in which the recessed box is shown in front section. All these fittings are to be made practically water-tight, as in a well-constructed magneto it is essential that the working portions should be so thoroughly enclosed as to prevent the admission of water, oil, or dirt of any kind. For this same reason it is customary to enclose the space between the top of the pole-pieces and the edges of the brass plates constituting the faces of the bearings, with a sheet of fairly stout zinc, faced internally with

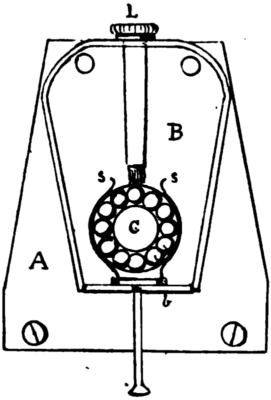

Fig. 13.—Elevation of back bearing.

A, The gunmetal plate; B, The recessed box (partly in section); C, The nozzle, cup, or bearing proper, showing the balls; *b*, Bottom cover, retained by springs *s s*; L, Lubrication (wick here shown).

cloth or felt, and retained in position by short screws entering into the top edges of the said bearings, of which there are two—one at each end of the spindle.

21. Insulation of Front Bearing.—These bearings may both be cast from the same pattern; but it must be noted that, as the front end (that at which the armature wire projects through the insulated spindle) carries the first contact-stud, by means of which the current flowing from the armature is taken to the "plug" in the combustion chamber, it must be insulated: to this end provision must be made for the insertion of two $\frac{1}{4}$ in. bolts, one at each lower extremity of this (the front bearing), which support the stout ebonite insulating rods, and the bracket. The bottom of the magnets, with their pole-pieces, is closed by a stout rectangular base, either in zinc or aluminium, and this is sometimes furnished with a flange at right angles to the said base, by means of which the magneto can be fixed to any desired and suitable portion of the body of the car. The operator will remember that *no holes*, except those previously mentioned, for fixing the magnets to the pole-pieces, are to be made in the magnets, so that all the attachments above mentioned are screwed either directly into holes made in the pole-pieces, or indirectly to the same by means of screws fitting in the front- and back-plates, which serve as bearings. Hence, the screws that hold the magnets to the pole-pieces must be stout and strong, and not less than twelve in number, six on each side. We proceed to show the arrangement of the insulated fixed contact on the front bracket, by means of which the moving contact-stud can deliver its current to the plug, notwithstanding its rotary or oscillatory motion. To effect this purpose the cross-bracket B, shown in elevation and section at Fig. 14, is insulated from the front bearing-plate A by stout ebonite pillars E E, and washers *e e*, while it, with its attached-terminal T, is in contact with

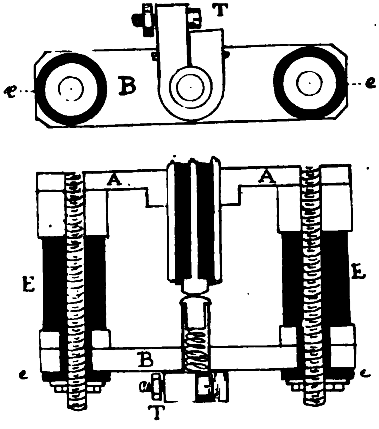

FIG. 14.

the live or outer armature wire through the fixed contact-stud (which is kept constantly pressing against the moving stud) by means of a little coiled spring let in the bearing at *b*.

22. Closed and Open Circuits.—The reader will notice that in the illustration we have supposed the magneto to be running on the *closed* circuit; that is to say, that the circuit is complete from one end of the armature wire to the other through the frame of the car, except only when an interruption is made in the circuit intentionally by means of the tappet. But, although this is the plan usually adopted, there are many magnetos in the market in which the contrary system is adopted; that is to say, in which the magneto runs on the *open circuit:* this means that no current passes until contact is made by the tappet, when the spark at the plug takes place. A little careful examination of the portions already illustrated will render the construction of such a magneto (without the movable shield or screen) perfectly clear and intelligible.

23. Contact Breaker Actuated by Two-to-one Gear.—We may now pass to describe the mode in which the current flowing from the armature is allowed to pass, or is interrupted in its passage to the sparking-plug, by means of a contact-breaker actuated by the two-to-one gear, so as to produce a spark in the combustion-chamber at the desired instant. The reader will remember that the spark produced is what is termed an "induction" spark, the strength of which is dependent on the induction set up by the numerous convolutions of wire (coiled round the armature) upon one another at the moment of making or breaking contact at any point in the circuit, and that, unless this sudden make or break in the circuit occurs, the E.M.F. of the current set up by the mere rotation or other movement of the armature would not have sufficient tension to produce a spark at the

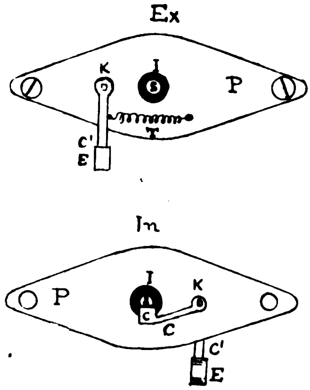

FIG. 15.—Contact breaker.
Ex., Seen from outside the combustion chamber; **In.**, Seen from inside the combustion chamber.

sparking plug. Although many means are adopted to secure this result, the annexed sketch (Fig. 15) will give an idea of a typical method of breaking (in the case of machines of the closed-circuit type) or of making this contact (in those of the open-circuit type). The reader must bear in mind that this contact-breaker very rarely forms part of the magneto proper, and that except only in the case in which the current from the magneto is made to actuate a coil is this required; but the current generated by the armature is taken off the terminal T, which projects, as shown at Fig. 14, direct to the plug by means of a sufficient length of well-insulated flexible cable known as "high-tension flexible."

24. Breaking Contact.—Let us suppose that we have a cylinder of some hard, infusible insulator, I (such as soapstone), of sufficient length to reach from the outside of the combustion chamber to its interior, into which it can be inserted as usual by means of a threaded cap, or (if it takes the shape, as in the illustration, of an oblong square) by means of side screws fitted to the outside of the said chamber. Through the centre of the aperture passes a stout steel rod, S, faced at one portion, where it is flattened, with a speck of platinum. This central rod is placed in connection with the live wire proceeding from the magneto by means of the said "flexible." Working in the plate P of this contact-breaker, we have a straight arm, C, bearing at its inner extremity, close to the steel rod, a little square. This is borne at K by a short spindle, which forms a trunnion for this arm extending from the inside to the outside of the cylinder; and bearing a cranked extension, C′, on the outside, this extension being at right angles to the inner arm C. By means of a coiled spring, T, this arm is drawn towards the centre of the contact piece, so that the little square C is retained in contact with the central rod S, unless C′ be forcibly drawn aside by anything striking against its lower extremity, E, when, of course, the contact between S and C being interrupted, a vivid spark would occur, and thus fire the explosive mixture.

25. Making Contact.—If it were desired to produce the spark by *making* instead of by *breaking* contact, as in the above example, the same appliance could be made use of; but in this case it would be necessary that the pull of the spring should be exerted in the opposite direction, to ensure that the two pieces C and S should only come in contact the one with the other at the instant when the cam on the two-to-one shaft strikes the prolongation E of the cranked arm. Although this arrangement is perfectly efficient, it labours under the disadvantage of being liable to be blown off the gland of the combustion-chamber under the force of the explosion, and therefore contact-breakers of almost precisely similar principle, but capable of being screwed into the usual threaded hole in the combustion-chamber, are now largely adopted.

26. Alternative Contact-breaker or Plug.—

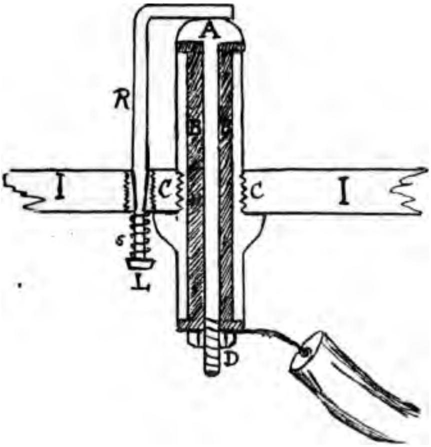

FIG. 16.

In order to render this portion of our subject complete, we illustrate at Fig. 16 another form of contact-breaker (or maker) which is free from the above objection, but which, of course, necessitates the shell of the combustion-chamber being perforated to allow of the passage of the striker-rod. This is usually borne in the centre of a little screwed plug, thus rendering its insertion and withdrawal a matter of comparative ease. The contact-breaker itself consists, then, of two portions—viz., a mushroom-headed metal core, A (usually of cast iron or nickel), passing through the centre of a plug of the ordinary ignition type, from which it is well insulated by means of a steatite or other fire-resisting insulator, B. This fastens into the combustion-chamber, I, by means of its screwed collar, C, and terminates at its outer extremity in a small nut, D, under which is clenched the live wire proceeding from the magneto. The other portion consists in the striker, S, which takes the shape of a rectangular piece of metal, forming an extension of the striker-rod, R. This striker rests against the mushroom head, A (if the magneto is working on the closed circuit), being maintained in that position by the action of a small spring, shown at S, on the outside of the combustion-chamber. The striker-rod itself, where it enters the plug screwed into the combustion-chamber, is slightly coned, with the result that the mere act of explosion tends to close the aperture through which the rod passes more tightly, and thus to prevent any escape of the explosive mixture. The outer end of this same rod, R, terminates in a little stud, L, against which the tappet, or any prolongation thereof, strikes at the moment it is desired to produce the explosion, which it does by suddenly interrupting the contact between the striker, S, and the metal cap, A, when a vivid spark is produced.

CHAPTER III

MAGNETISATION

Magnetising field magnets—Permanent magnet—Electro-magnet—Continuous-current dynamo—Wire helix—Temper.

27. **Magnetising Field Magnets.**—Having thus described the essential parts of the magneto proper, we will turn our attention to the methods usually adopted for magnetising the field-magnets, which hitherto have only been forged, bored, and fitted. They now require hardening in the usual manner, and this operation must be carefully conducted so as to produce the desired amount of hardness without rendering them too brittle. They must be so hard that a file will not touch them; but at the same time they must not be hardened to such an extent as to cause them to break if tapped with a gentle blow from a light hammer. If they be tempered sufficiently to enable them to cut the surface of cast iron, they will be hard enough. If left too soft, although they will take up magnetism more readily, they will, on the other hand, lose the magnetism thus acquired with

great ease; if the hardening be carried to the point of brittleness, they will be very slow in acquiring their full magnetism; but, on the other hand, will retain it. There are three methods by which the magnets can be successfully magnetised: 1st, by means of a powerful permanent magnet, known as a "king magnet;" 2nd, by means of a powerful electro-magnet, or a dynamo which is running; and 3rd, by means of a coil of wire round which a current of electricity is flowing. This latter is usually designated "a solenoid."

28. Permanent Magnet.—If a permanent, or king, magnet be used, this had better be of the horseshoe form, and should be very massive, with a space between its limbs nearly as great as that existing between the limbs of the field-magnets which it is proposed to magnetise. The reader will remember that he has been advised to mark one of the poles of each of the magnets made with a letter N, and he will be careful in magnetising these, to render *these* poles north, by placing the S pole of the king magnet on or against this N pole of his new magnets, the N pole of the king magnet at the same time striding over and resting upon the opposite limb of the new magnet. He will then draw the king magnet along the surface of the new magnet in this position until he reaches the bend, when he will return to the poles again, and here lift the king magnet up, and right away from the new magnet. He will then replace it (still in the same position with regard to its poles) on the bend of the new magnet, and stroke along it from bend to extremities, again lifting and replacing on the bend, repeating this operation many times (until, in point of fact, the magnet has acquired as much magnetism as it will take up on *that* surface), remembering always that the final stroke must be from bend to poles, at which point the king magnet must be removed from the new magnet. The new magnet is now reversed—that is to say, its other edge is placed uppermost, and subjected to the same stroking treatment, great care being, of course, taken that the correct poles be used in juxtaposition (the S. pole of the king magnet against the N. pole of the new magnet, and *vice versâ*), otherwise the magnetism already imparted will be annulled. We still have to magnetise the new magnets on their wider faces; and this is best done by placing the king magnet (with its poles in the correct position) on the wide face of the bend, and then stroking the magnet from end to end a sufficient number of times, never allowing the poles of the king magnet to pass beyond those of the new one, and finishing by lifting and removing the king magnet when it arrives at the middle of the bend, and *not* when it is near the poles.

To do this work efficiently, the king magnet itself must be of sufficient strength to lift at least 30lb.

29. Electro-magnet.—If a "king magnet" of sufficient power be not available, even better results can be obtained by the use of an electro-magnet of the form and approximate dimensions given in Fig. 17, made from a bar of round, soft iron, 1 in. diameter, 18 in. long, bent as shown, to stride over both limbs of the new magnets. When thus bent and forged to shape, both poles being filed perfectly flat and level, this horseshoe is to be wound, as shown, with about 4lb. No. 18 double cotton-covered copper wire. If the two free ends of the winding wire be coupled to the terminals

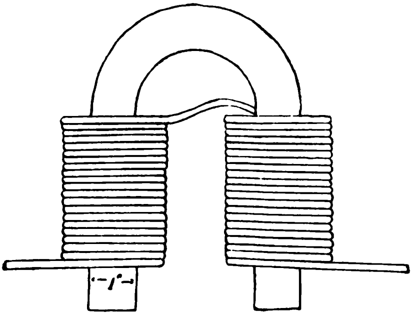

FIG. 17.

of a 4v. accumulator, this electro-magnet will be found capable of lifting about 1 cwt. Care must be taken when using this, *always to connect* the same terminals to the *same* wire ends: otherwise the polarity will be reversed.

With such a magnet, powerful magnetism can be easily imparted by stroking the steel bars or horseshoes precisely as indicated in our former section. Whether a permanent king magnet or a temporary electro-magnet be employed, the operator will remember that by striking the steel of the new magnet, or "tapping" it several times while it is under the influence of the magnetiser so as to make it ring, will greatly facilitate the acquirement of magnetism—probably in virtue of the fact that the vibration thus set up permits the constituent molecules of the steel to take up the polar position which constitutes magnetism.

30. Continuous-current Dynamo.—Another mode of imparting magnetism is by means of a continuous-current dynamo. While a dynamo is running the two pole-pieces become powerfully magnetised. Hence, if by means of a compass-needle the polarity of these be noted, so as to recognise which is north and which south, it is easy to magnetise our new magnets by placing the pole that we desire to make south against the north pole of the dynamo, and that which we wish to make north against the south pole of the dynamo, using the same precautions of clanking the new magnet against the dynamo-pole several times, so as to bring about the vibratory motion just mentioned,

31. Wire Helix.—There is yet another manner of imparting magnetism to the steel horseshoes, and that is of making a helix of several hundred turns of No. 18 cotton-covered wire, as shown in Fig. 18, of such an internal diameter that it can be passed from end to end of the same around the bend. If now a current of electricity (of not less than 6 ampères) be passed through a helix of about two hundred turns, and this latter be drawn over the horseshoe several times from end to end, the horseshoe will become powerfully magnetised.

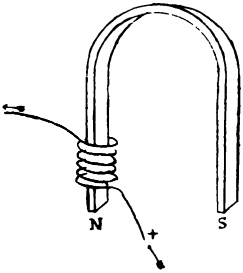

FIG. 18.—Magnetising by a wire helix and battery.

The operator will bear in mind that *that* end of the magnet will become *north* which is *under* the wire or wires carrying the positive current, the north pole being found to the *left hand* of this entering current. Our Fig. No. 18 illustrates by the arrows the direction of the current and the polarity of the resulting magnet. As before, while this operation is going on, it will be advisable to tap the steel horseshoe repeatedly, and if the circuit between the battery and the helix of wire be frequently broken, the result will be even more satisfactory. This latter method, though perfectly satisfactory when magnetising small magnets, is not so well adapted in the case of large ones, as very heavy currents are then required. We therefore give the preference either to the separate electro-magnet system figured at 17, or else to the dynamo method, which, if the dynamo is one giving at least 1 kilo-watt, will be found eminently satisfactory.

32. Temper.—Before closing this portion of our subject, we might mention the best *temper* is that usually imparted to the steel required for files and other cutting tools for cast iron, and should in no case be deeper than *pale straw.*

CHAPTER IV

THE ARMATURE SCREEN AND ITS FUNCTION

Advantage of shield—Effect of shield when in line with pole-pieces—At right angles—Inclined to pole-pieces—Influence on current—"Timing" by use of shield—Retardation and advance of spark—Control of shield—Principle of "timing"—"High tension"—"Sparking" by tappet-rod and cam—Modified shields and armatures.

33. **Advantage of Shield.**—We can now pass to the consideration of magnetos in which a screen or shield can be inserted between the pole-pieces of the field-magnet proper and the armature, and this, whether the armature itself be made to partake of a rotary or an oscillatory motion, or whether it be held immovable while the screen or the shield be caused to move. One of the chief advantages in the employment of the screen is the power that it gives us of altering the position of the "field of force," and of thus "timing" the occurrence of the spark.

34. **Effect of Shield in Line with Pole-pieces.**—Before describing the different modes in which the screen can be utilised, it will be well for the

reader to glance at the annexed illustration, so as to form a clear idea of the manner in which it acts. For instance, at Fig. 19 we have a sectional illustration of the pole-pieces of one of our magnets, A A, in which at B B we have the two segments of circles which constitute the shield or screen proper. These, as we have already described

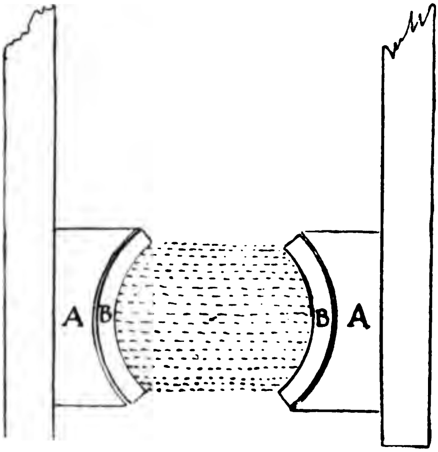

FIG. 19.—Section of pole-pieces with shield in line with them, showing lines of force.

and figured at our illustration, Fig. 9, are carried by the discs at the end, and if shifted move simultaneously. They are made to run so closely to the pole-pieces themselves that, when they are placed as shown in our illustration, they practically become magnetically part and parcel of the field-magnets themselves, and consequently send their lines of force across the tunnel, impinging upon anything (armature, etc.) which may be rotating or oscillating therein. Hence, while in this position, they do not act as a shield at all, but simply bring the pole-pieces into close proximity to the iron of the armature.

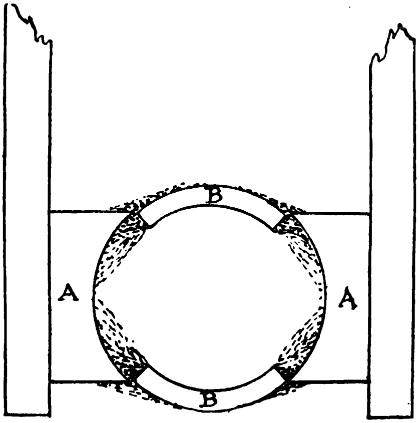

Fig. 20, in which the shield BB is in such a position as to complete the magnetic circuit, and thus prevent the lines from traversing the tunnel.

35. Effect of Shield at 90° to Pole-pieces.—Let us now imagine an extreme case, as shown at Fig. 20, in which the shield is placed at right angles to its former position. The result of this position is, that the lines of force emanating from the poles of the magnet, finding themselves almost in contact at the extremities of their gaps with the terminations of the shield or screen, find a ready passage to complete their magnetic circuit through the said screen (which is of soft iron, and, therefore, affords a free passage for the completion of the circuit). Consequently, nearly all the lines of force which otherwise would traverse the tunnel from pole-piece to pole-piece are now concentrated on the screen while the aperture or tunnel is left void of any such lines.

In our illustration, to avoid confusion, we have in this latter case shown the tunnel as being absolutely free from lines of force. As a matter of fact, some few do traverse the space, but, owing to the fact that their magnetic attractions and repulsions act with forces which are inversely as the square of the distance, it follows that, as the shield now finds itself very much closer to the most active portions of the magnets (and also to the armature, which runs in the tunnel), the said shield absorbs practically all the lines of force, very few straying as far as the armature. This fact can be experimentally proved by any one possessing a magneto in which there is a movable shield, by first placing the said shield in a line with the pole-pieces and then attempting to rotate the armature by hand; proceeding afterwards to make the same attempt after the shield has been placed at right angles to the first position. In the first instance, he will encounter very considerable opposition in causing the armature to rotate; in the second case, he will find practically no difficulty in rotating the armature with a very small exertion of force.

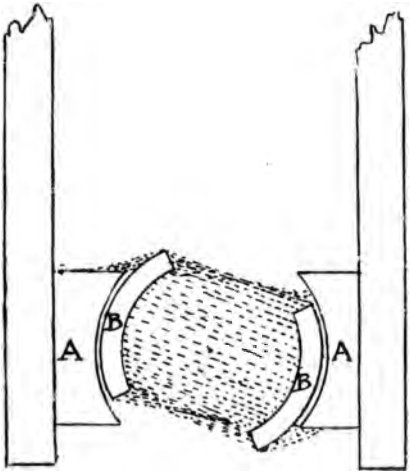

Fig. 21.—**Displacement of lines of force, consequent upon shifting the shield BB through a small angle.**

36. Effect of Shield inclined to Pole-pieces.—We may now pass to consider the effect of shifting the shield through a few degrees of arc, as illustrated in Fig. 21. Here, again, the shield becomes powerfully magnetised, under the influence of the pole-pieces, with the result that the lines of force traverse the tunnel, producing a field which is somewhat distorted, as shown in Fig. 21, so that an armature rotating in this field will have the *time* at which the current attains its maximum intensity somewhat delayed with regard to the direction of rotation, if the armature be rotating *clockwise,* or advanced if it be rotated *counter-clockwise.*

37. Influence on Current.—In this illustration, as before, we have only depicted the main lines of force, leaving out, to avoid confusion, the stray lines which, to some small extent, also traverse the tunnel. We may now consider the case of using a fixed armature and a rotary shield, simply for the purpose of setting up the current, without the intention of altering or controlling by means of the shield the instant of greatest electrical intensity. In this case, the armature will stand with respect to the magnet and pole-pieces as shown at Fig. 22, A, the shield being indicated by the segments at B B. It will be remembered that, in order to generate current, the conductors C C, with which the armature is wound, must be cutting lines of force, either by rotating across them, or by the lines themselves being suddenly caused to impinge upon them, or to be cut off *from them.*

Now, we will suppose the two segments, B B, of the shield to be revolving round the fixed armature. While they are in the position shown in the illustration, *they* are sending all their lines of force *across* the conductors of the armature; but when, during the process of rotation, these two segments find themselves bridging across the gaps between the pole-pieces, as in Fig. 20, no lines, or practically no lines, impinge upon the conductors, so that no current is generated. The reader will readily perceive that, in order to set up these waves of current, it is by no means

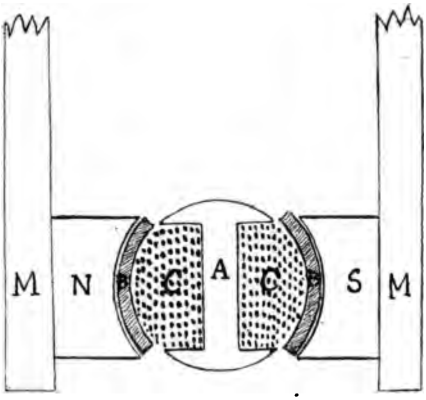

Fig. 22.—Showing shield increasing the action of pole pieces.
A, The armature; B B, Segments of the shield; C C, Sections of the conductors; M M, Portions of the magnet; N S, Pole-pieces.

essential that either the shield in the one case, or the armature in the other, should perform *complete* revolutions. To secure the end in view, it is quite sufficient that the shield, or armature, should be able to oscillate through an arc of about 90° from side to side. In either case, the E.M.F. and quantity of the current will, *ceteris paribus*, be dependent on the speed of rotation or oscillation.

38.—"Timing" by use of shield.—As one of the most useful properties of the screen or shield is the power it gives us of controlling the time at which the spark shall occur (which should be coincident with the instant at which the greatest number of lines of force are passing through the conductors on the armature), we shall first devote our attention to the consideration of a magneto in which the shield has been placed, or is capable of being placed, in any desired set position with reference to pole-pieces, and has an armature working within it, either by being rotated or oscillated.

Let us suppose the screen or shield to have been set in the position shown in Fig. 19, in which the lines of force are projected straight across the tunnel. It is evident that the point in its rotation at which the conductors wound in its channels (see C C, Fig. 22) will cut the greatest number of these lines of force will be when the said conductors are facing the two segments of the shield (as shown in Fig. 22), and consequently this will be the position at which the electricity set up will be at its highest intensity; hence, the time at which the spark should be taken at the sparking-plug, either by making or breaking circuit therewith.

39. Retardation and Advance of Spark.—We will now presume that the motion imparted to the armature be *clockwise.* As the armature continues its rotation its conductors cut fewer lines, gliding between them until the position of the conductor is at right angles to that shown, when little or no current is set up. Should the motion be continued, again an increasing number of lines is cut, *but in the opposite direction,* so that the current again rises in quantity and in tension, until another maximum is reached, when the conductors are again facing the screen. But, supposing that for any reason it be desired to retard or advance the time of the production of the spark at the firing-plug, without altering the existing arrangements at the contact-breaker, it is evident that this can easily be done by altering the position of the shield, since, by taking the shield through a small angle of arc, in the same direction that the armature is rotated, the field will be proportionately distorted in that direction; consequently, the period at which the armature will reach the intensest point of field will be correspondingly delayed, and the spark retarded to the same degree. An examination of Fig. 23 will render this matter perfectly evident. In like manner, if the shield be moved a few degrees of arc in the opposite direction—that is, opposite to the direction of rotation—the production of the spark will be advanced.

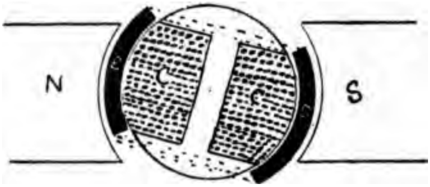

FIG. 23.—Spark delayed, by shifting the shield slightly in the direction of rotation of armature.

40. Control of Shield.—It will be understood that this power of retardation and advance by means of altering the position of the shield is, in this instance, entirely under the control of the driver, as the exact position of the shield is set or altered by means of a controlling lever on the quadrant. Sometimes the armature does not perform an entire revolution, but only oscillates under the influence of a cam on the two-to-one gear. Lastly, the armature may be held perfectly motionless in the position shown at our Fig. 22, while the shield itself is made to oscillate by means of a lever, as shown in our Fig. 24 and

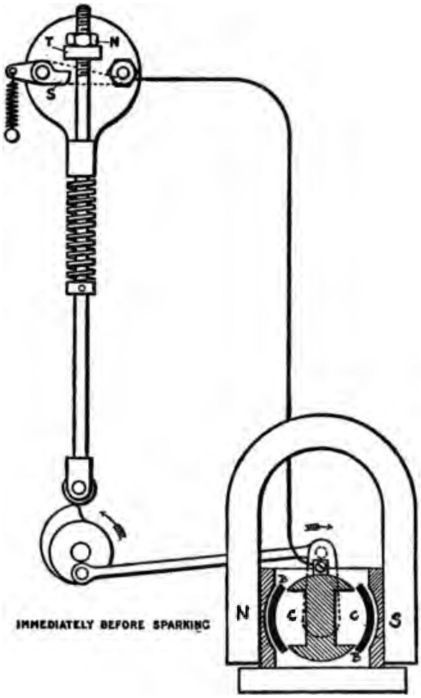

Fig. 24.

Fig. 25, in the former of which the shield is shown in the position it occupies just before sparking, while in the latter the shield has shifted through a small angle through the tappet-rod sliding off the cam, and, at the same time, breaking contact between earth and the sparking-plug, thus allowing the spark to flow across the points or other contacts of the firing-plug.

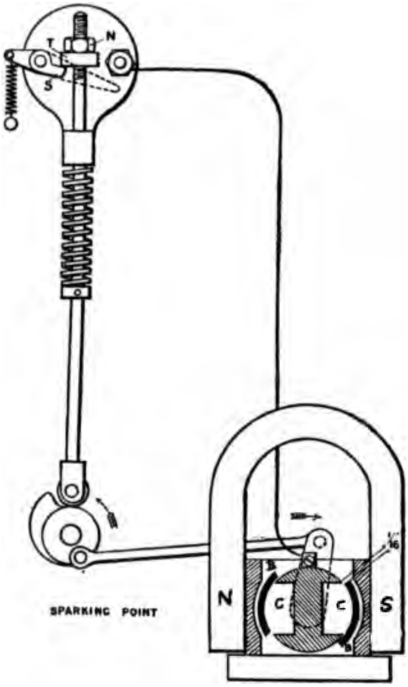

FIG. 25.

41. Principle of "timing."—We should recommend the reader to study carefully these last two illustrations, as not only is the manner in which the shield affects the magnetic field well illustrated, but also the mode in which the actual timing of the spark at the firing-plug is made to coincide with the point of maximum intensity of the said field. Of course, numerous modifications in the contact-making or breaking device are to be met with; but if the reader once grasps the principle of action of these arrangements, he will have no difficulty in understanding the alterations introduced by the different makers. There is one point, however, which must be borne in mind—and that is, that while on the one hand some makers prefer that the circuit should be complete between the magneto and the frame until the spark is required, so that when the circuit is broken the spark is produced—this method being known as the "closed circuit" system; on the other hand, some give the preference to leaving the circuit interrupted (or open) until the spark is required, when, contact being made, the spark is produced.

42. "High Tension."—We shall revert to the different modes of causing the spark to occur at the desired intervals when we consider those forms of magnetos in which the current from the armature winding is not taken directly to the sparking-plug, but is intensified either by means of being passed through an independent sparking coil, or by enveloping the primary winding on the channel of the armature with a well-insulated winding of secondary wire, by which means the tension of the resulting current is very greatly increased. Such magnetos are known as "high tension."

43. "Sparking" by tappet-rod and cam.—In many excellent machines, such as the Bassée-Michel, the Peugeot, etc., no shield at all is employed, the regulation of the sparking being effected entirely by the tappet-rod and cam. In some instances which have come under our notice, in which no shield is employed, the desired alteration in the position of the field is effected by carrying the field-magnets a few degrees of arc to the right or left of the axis of motion of its armature.

44. Modifications of Shield and Armature.—Still, in the hands of a skilled workman, who knows how to set and adjust the shield, the presence of the shield gives him considerable latitude in the range of timing the spark. It would be hardly necessary here for us to dilate on the modifications in the construction of the armature and shield, when the motion of one of the two is dispensed with, since we have shown, in our first articles, that the shield should be made so as to be capable of rotation round the spindle of the armature when such motion is required; while, on the other hand, when it is desired to arrange the machine so that the armature should rotate or oscillate, it can do so freely on the extremities of the tube carrying the caps of the shield as bearings, these latter being themselves held immovable in any desired position by means of a set-screw or otherwise. In order to show how an oscillatory motion may be imparted to the shield or to the armature by the aid of a rod swivelled on the face of an eccentric on the shaft, we illustrate at Fig. 26 an old form of Simms-Bosch low-tension magneto, in which the shield alone can be made to oscillate under the impulses of the adjustable or telescopic rod actuated by the eccentric on the shaft.

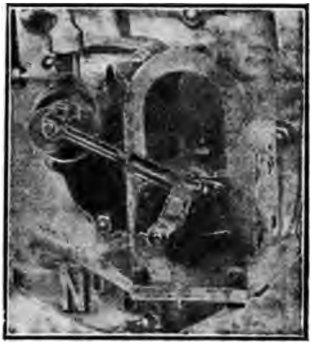

Fig. 26.—Mode of imparting oscillatory motion to shield

CHAPTER V

HIGH TENSION MAGNETOS

Induced currents—Intensity and volume of induced currents—Back currents—Condenser: its materials and construction—Position of condenser—Simms-Bosch high tension magneto—Eisemann high tension magneto—Gianoli high tension system.

45. Induced Currents.—In the machines we have hitherto been considering, the current, whether set up by the motion of the armature or of the shield, and whether alternating or continuous, is conveyed by means of the live wire passing through the insulating spindle of the armature *directly* to the plug. In those we are about to study, the current is not utilised in this manner at all, but is made to set up a second current of very much higher tension in another piece of apparatus, which secondary current is the one utilised for the production of the spark. We here propose to show how this is done. We will suppose the reader to have sufficient acquaintance with the production of currents by induction to know that if we send an interrupted current along a wire (whether bent into the form of a helix or in one straight length, is immaterial to the results), another current will be set up in the opposite direction along a second wire lying parallel to the first or primary wire at every time the alterations or interruptions in the first or primary wire take place. Let us suppose that we have 150 inches of, say, No. 16 cotton-covered copper wire, coiled into a helix round a 1 inch core; and either over it, or alongside it, another separate and distinct helix consisting of the same amount and gauge of similar wire. On making and breaking contact with any source of electricity and the first helix, it will be found that a precisely similar current will be set up in the second helix.

46. Intensity and Volume of Induced Currents.—Furthermore, if the number of turns of wire on the second helix be doubled, so that rather more than 300 inches of wire be employed, the tension of the current set up in the secondary coil will be approximately double that employed in the primary coil; in other words, the tension of the current set up in the secondary coil is directly proportional to the ratio existing between the number of turns on the primary and secondary coils. Another point which must be noted is that the volume of current (in ampères) set up in the secondary coil, will vary in like proportion; that is to say, as the number of turns in the secondary coil *increases*, so the volume of current *decreases*. Therefore, if a primary coil of one hundred turns is fed with a current of one ampère, at one volt pressure, and over it be wound one thousand turns of secondary wire, we shall find that we can get a current of one-tenth of an ampère at 10 volts pressure from the extremities of the secondary, when the primary current is interrupted in the primary; and as the section of the wire required to carry one-tenth of an ampère is one-tenth of that required to carry one ampère, we may use a very much finer wire for the secondary than was required for the primary. Hence, it is customary to use a comparatively coarse wire for the primary and a much finer wire for the secondary, with a view to economise space, and also to keep the secondary wire in the most intense portion of the magnetic field.

47. **Back Currents.**—Before proceeding further with the details of making up these "high tension" magnetos, we must point out some other peculiarities connected with the behaviour of wires along which interrupted currents are being sent. It is found that if such a wire be bent into the form of a helix of many convolutions, each spiral will react on its neighbour, so that in a

coil of one hundred turns there will be during the passage of one flow one hundred oppositions in the helix—one for each turn—and these oppositions (which take the form of a back electromotive force, of equal intensity to that of the current sent) would greatly interfere with the induction effect set up on a secondary coil, unless some means were found of taking up this "back" current. In like manner, at the moment the primary current is interrupted, and the primary wire falls back into its neutral condition, a second current, in the same direction as the primary current, now traverses the helix; but this, thanks to its being in the same direction as the primary current, so far from annulling its effects, strengthens them.

48. Condenser: its Materials and Construction.—It is, therefore, essential in using primary and secondary windings, whether on the same armature or in a separate coil, to have some means of picking up or storing this back electromotive force, and turning it to good account, instead of allowing it to interfere with the desired inductive effect on the secondary. For this purpose an arrangement called a "condenser" is essential, and the following details of its construction, which apply equally whether intended for use in high tension magnetos or in coils (actuated by batteries), will be of service. About 51 sheets of good, but rather thin, paper, absolutely free from pin-holes, metallic spots, or other blemishes which might allow the passage of electricity, are now prepared, and cut into oblong squares of exactly equal size (this dependent on the size of the machine into which they are to fit). A convenient size for coils is 5 in. long by 2½ in. in width; 50 sheets of tinfoil, say 2 in. wide by 5 in. long, are also cut. A sufficient quantity of paraffin wax is now melted in a perfectly clean, flat tin dish over a gentle burner or a spirit lamp, and the sheets of paper one by one are immersed into this melted paraffin, drawn out against the edge of the dish to drain off all superfluity of melted wax, and hung up on a stretched line to drain and harden. Care should be taken to drain off as completely as possible any superfluity of wax by drawing the papers along the edge of the dish, as it is essential that the papers be perfectly evenly coated, and free from any blobs or patches of congealed wax. When the required number of sheets has been thus prepared, a piece of soft flat board (planed on its upper surface) is chosen, and one of the sheets of paper laid flat upon it. Eight pins are placed, two at each corner, at about three-quarters of an inch apart, as shown at Fig. 27, so as to prevent the sheets of paper moving during the succeeding operations. A sheet of tinfoil is now taken and laid over the sheet of paper, leaving a quarter-inch margin all round, except at what we shall call the *lower* edge, where the tinfoil will project over about a quarter of an inch.

Another sheet of paper is now laid upon this,

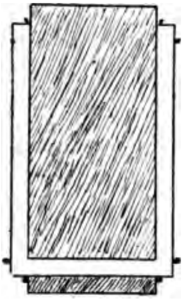

FIG. 27.—Building a Condenser.

and over this another sheet of tinfoil, with this difference: that the tinfoil must overlap the paper at the *upper* or opposite edge of the 2½ in. side, instead of at the lower edge. Again, another sheet of paper is placed over the second tinfoil, followed by a third tinfoil sheet, again overlapping at the bottom or lower edge, and therefore in contact with the tinfoil below. In like manner the remaining sheets of paraffined paper and of tinfoil are placed one over the other, with the alternate tinfoils overlapping at opposite ends of the paper sheets, as above described, until the whole tally of papers and tinfoils have been laid on, terminating, as we begun, with a sheet of paraffined paper. As each sheet is laid on, the papers should be firmly pressed together, which, owing to the plasticity of the paraffin wax, will cause them to adhere. When this has been neatly done, the operator will prepare two squares of rather stout cardboard of the same size as the paper sheets (in the example given 5 in. by 2½ in.), soak these in melted paraffin wax, and, when set and hardened, will, by passing the blade of a thin knife under the prepared sheets, lift them bodily without disturbing their arrangement, and place them on one cardboard, cover them with the other, and bind them together tightly with a wrapping of rather wide tape laid on spirally, and stitched down one end, remembering to leave protruding beyond the cardboards the free ends of the tinfoils which project beyond the paper. A piece of No. 20 copper wire, about 7 in. long, drawn perfectly straight, is placed at its middle across one of these projecting ends, the tinfoils rolled tightly round it, and stitched down to it by means of a piece of black thread. The projecting ends of the wire are then bent over the tinfoil roll thus produced, and twisted tightly together for after-connection, where required. The other extremity of the tinfoils are served in precisely similar manner, with the result that we have an arrangement of 25 sheets of tinfoil connected in parallel one with the other, separated by 25 sheets of paper from other 25 sheets of tinfoil, likewise in parallel among themselves, each set being furnished with its own separate connection. This arrangement constitutes a "condenser," or "capacity," so that if a charge of any given nature be communicated to the tinfoils of one set, a charge of opposite nature is acquired by the tinfoils of the opposite set, and this charge cannot be dissipated except through some path left open between the two connections. We give (Fig. 28) an illustration of a finished condenser of this type.

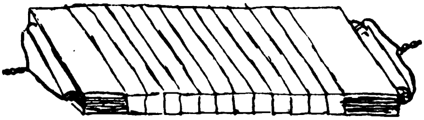

FIG. 28.—Condenser completed.

49. Position of Condenser.—Whatever be the system adopted for setting up the high tension current in the secondary winding, whether it be an independent coil or whether it take the form of coils of fine wire insulated from, but superimposed on, the primary, the position of this condenser will always be the same, namely—its two terminals, *i.e.* the two twisted wires which are individually in contact with the two sets of protruding sheets of tinfoil, must be electrically in contact with the two ends of the primary circuit at which the " break " or " make " of contact takes place, to enable the "extra" or "self-induced" current to pass into and charge the two opposite sets of coatings of the condenser.

50. Simms-Bosch High tension Magneto.—These precautions being premised, we will pass on to the consideration of a typical form of magneto, in which the secondary winding is on the same armature as the primary. The one which we select for the purpose of illustrating the principle is the one known as the "Simms-Bosch high tension" magneto, illustrated in sectional elevation at Fig. 29. In this we have a set of three powerful steel magnets, with pole-pieces as usual. The armature itself is stationary, having two windings, one consisting of a few turns of coarse wire, and the other of many turns of well-insulated fine wire, thus simulating the iron core, the primary winding, and the secondary ditto of an ordinary induction-coil. Those who are interested in the construction of the ordinary induction-coil as adapted for ignition purposes will do well to refer to the author's little book, "Ignition Devices for Gas and Petrol Engines." Over this is a rotating soft iron sleeve, having two slots, as illustrated at Fig. 9, that is, fitted between the pole-pieces and the armature. At one end of this latter is mounted a piece of mechanism, consisting of a contact-breaker or interrupter, of which we have recently described the construction, the object of which is to suddenly break the primary circuit when the current induced therein by the partial rotation of the soft iron sleeve has reached the point of maximum strength. The condenser is fixed in a small case in a recess just over the armature, and is connected to the primary or coarse wire circuit of the said armature by means of two wires as shown. The sudden

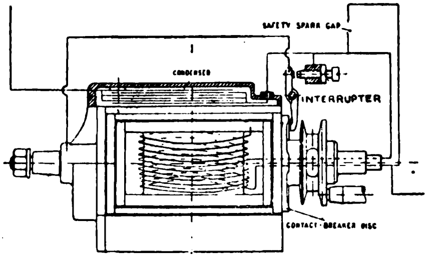

FIG. 29.

interruption of the primary current by the contact-breaker or interrupter brings about a high tension current in the secondary winding; one end of each winding is connected as usual with the metal-work of the machine, and the other ends are carried through suitable insulators to metal rings, whence the current is collected by carbon brushes pressing against them, and transmitted to the sparking-plug by an insulated cable in the usual manner.

51. Eisemann High tension Magneto.—Another form, perhaps familiar to the reader, is known as the "Eisemann," in which the secondary or high tension winding is entirely separate from the primary. Our Fig. 30 gives a typical illustration of this form of high tension magneto. In this we have the ordinary magneto with an ordinary H-armature, wound with coarse wire, rotating between the pole-pieces in the usual manner, no sleeve being used. The current produced in the armature is conveyed directly to the primary windings of an ordinary induction-coil, as shown at the bottom right-hand corner of our illustration, being connected in its path thereto to the condenser and to a contact-breaker or interrupter worked by a cam, the condenser being, as usual, placed in shunt with the interrupter. It will be seen, from the illustration, that the primary or armature current is entirely independent from the secondary or coil current, and the occurrence of the sparks is regulated so as to take place at the point of maximum effect by the adjustment of the relative positions of the cam actuating the interrupter and the arrival of the armature in the field of maximum intensity. It is, therefore, the negative wire proceeding from the core alone which is earthed or taken to the frame, and *not*, as in the former instance, the one proceeding from the armature.

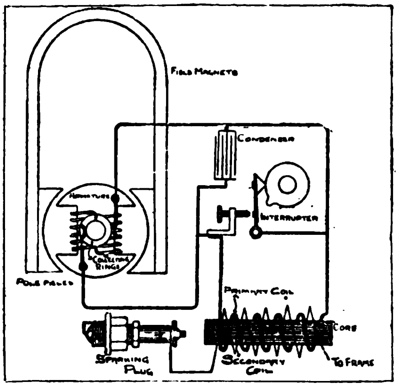

FIG. 30.—The Eisemann Magneto, with its separate coil. (No shield.)

52. Gianoli High tension Magneto.—In order to render the comprehension of this subject as clear as possible, and to facilitate the operator's work in case he has to deal with magnetos of peculiar patterns, we now proceed to describe an ingenious system of construction, in which the regulation of the time at which the spark is produced is controlled automatically by means of a magnetic device that comes into play only at the instant when the current reaches the point of maximum intensity, thus closing (or breaking) the circuit at the most favourable moment. This system is known as the "Gianoli High Tension." In this we have an ordinary magneto with soft iron sleeve and a double-wound rotating armature, along with its relative condenser. At. Fig. 31, we give a somewhat shortened sectional elevation of the Gianoli magneto. The main point of difference lies, as we have already said, in the

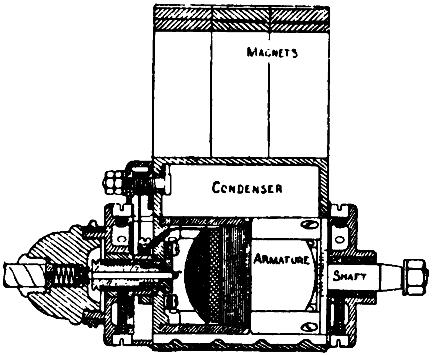

FIG. 31.—Sectional view of Gianoli High tension Magneto.

manner in which the high tension current produced by the sudden interruption in the primary circuit is set up invariably when the armature finds itself in the most favourable position, and this is brought about, not by means of a mechanical make-and-break device, such as a cam and

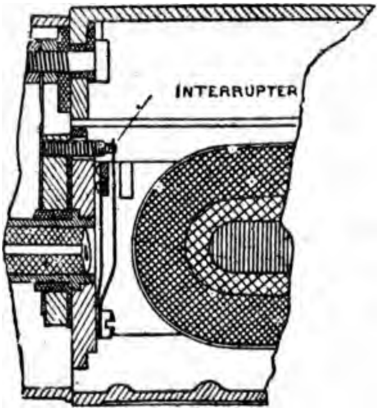

Fig. 32.—Front and sectional view of Gianoli Armature, showing automatic electro-magnetic make and break.

rocker, but by an electro-magnetic vibrator or interrupter, which we show in section on the portion of the armature illustrated at Fig. 32. To the extreme left, held by a screw shown towards the bottom of the figure, is a thin plate of soft iron, held in position by a double spring, both these being secured by the screw shown at the end of the spring. On the end of the armature cheeks are polar extensions, and the soft iron plate on the end of the spring is normally so adjusted as to be two or three millimetres away from the polar extensions. On one of the springs is a platinum contact, which abuts and presses against another platinum contact at the end of an adjustable screw. When together these contacts close the primary circuit; but, as soon as the polar extensions of the armature come opposite the soft iron plate, this plate is strongly attracted, and, striking against the platinum contact, breaks the circuit. The armature core, by the process of induction between the poles of the magnets and the circulating of the induced current, also becomes a magnet, and it is by virtue of this that it attracts the soft iron plate and causes the interruption. The attraction of the soft iron plate is rapid at all speeds, thus producing a succession of sparks at each period or phase of the armature's rotation. This enables the starting to be easily accomplished. Another important advantage gained is that, no matter how fast the armature be driven, it is impossible for an excess of current to be generated. The vibrator acts, in fact, as a perfect electro-magnetic governor, and always breaks the circuit at the same voltage irrespective of the speed. The soft iron sleeve, by means of which ignition can be advanced or retarded, is made to fit so closely to the pole-pieces as to be practically in contact with them. These, along with the armature and interrupter, are shown in our Fig. 33.

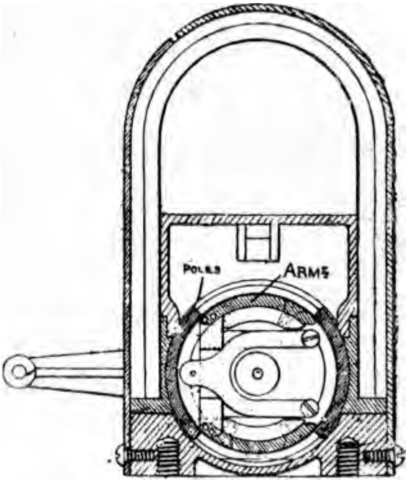

Fig. 33.—Front view of Armature, movable extension of pole-pieces, and electro-magnetic contact breaker of the Gianoli High tension Magneto.

CHAPTER VI

A FEW PRACTICAL HINTS

To insure correct timing—Adjustments of lever—Adjustments of tappet rod or cam—Ignition by alternating currents—"High" and "low" tension compared.

53. To Insure Correct Timing.—Having thus described the principal variations which may occur in the magneto proper, we pass to consider what the operator (called upon to adjust or repair such machines) often finds somewhat puzzling. We refer to the setting of the movable portion, be it shield or armature, so as to insure correct timing. We will then close the subject by a comparison between the merits and demerits of the two rival systems—viz. "high tension" and "low tension." When the armature rotates and does not simply oscillate, the timing is not such an essential part of the setting as in the case in which either the shield or the armature performs an oscillation only; we will therefore begin by supposing that the armature is a fixture, the shield only oscillating. Now, the best position for the armature to spark will be when the fixed armature has its conductors facing the pole-pieces, or, what amounts to the same thing, when the screen or shield has its two cheeks opposite to the two cheeks of the pole-pieces. Then all the lines of force are, as already seen, concentrating themselves upon the conductors round the armature. But, in order to affect the armature, *motion of the shield* must take place. If the motion be *from* the poles *towards* the gaps, the current is set up in one direction, and if, on the contrary, the shield be brought from a position of lying between the horns of the pole-pieces towards that of lying facing the pole-pieces, the current produced is in the opposite direction. It is really indifferent which of these two motions is given to the shield or to the armature: it is usual, however, that the lever or arm which imparts the movement to the shield (or armature) should,

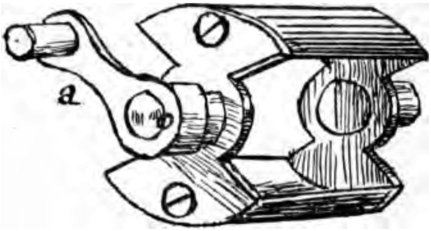

FIG. 34.

under the impulse of the cam, give the movement in the direction of the hands of a clock. The amount of motion to be given varies but little with the different machines; it never exceeds 90° of arc, and is generally rather less than this, but is seldom less than 60°. Now the portion that may possibly get out of order is the little lever (see Fig. 34, a), which is rigidly attached to the oscillating shield.

54. Adjustments of Lever.—Dependent upon the manner in which it is connected to the shield, this lever may have shifted slightly in position, or got bent, so that it may receive and communicate its impulse to the said shield *too early* or *too late* to produce the best effect. The first step, therefore, towards remedying this defect is to ascertain (either by actual inspection or by trial) *when* the conductors face the pole-pieces, and whether the motion of the shield when it oscillates be such as to expose the armature to the flux of the greatest magnetic intensity. If it is convenient to take off the zinc cover from over the armature tunnel, this point can easily be ascertained by inspection only; and a mark, easily visible from the outside, should be made, indicating the position in which the conductors on the one hand, and the shield on the other, face the pole-pieces. Now, these should coincide with the instant of best spark production. If they do not, the arm or lever that conveys the oscillating motion must be so fixed or straightened that they do thus coincide the one with the other. Of course, if there is considerable wear in the bearings, these latter should be rebushed; but the fault, if any, will generally be found to lie in the direction of a shifting or distortion of the lever itself. Sometimes it is not easy or convenient to take the magneto to pieces. A very fair idea may be got of the relative positions of the two moving portions by noticing where the greatest resistance is found on attempting to make the lever (usually actuated by the cam) to perform its motion. It will be noticed that at the beginning of its stroke little or no resistance is felt, this resistance increasing to a maximum, and then rather suddenly falling off. Now, if the portions (screen and armature) are in their proper relative position with reference to the lever, this point of greatest resistance should be about mid-way along the stroke, and any deviation from this position would be suspicious, and would demand immediate attention.

55. Adjustments of Tappet Rod or Cam.—It may require that the tappet rod be lengthened; this can be done either by unscrewing for a turn or two the nuts above, or by inserting a cheese-headed screw at the bottom of the tappet rod where it rests against the cam, and then filing it to the right length and carefully smoothing it so that it shall slide freely over the cam. If the cam itself be seriously worn, the ear thereof may be thickened by the addition of a piece of metal, or, better still, removed and replaced by a new one. In all cases when these adjustments have been made to facilitate future operations or repairs, it will be well, once having found the correct relative positions of the parts, to make distinct file-marks to indicate the correct position of the different portions.

56. Ignition by Alternating Currents.—It may aid the comprehension of this portion of our subject if we give here a brief description of the magneto and its timing-gear sent out by one of the most famous French makers. The magneto in question is furnished with an armature I, made of soft iron, the channel of which is wound in the usual manner with insulated copper wire. No shield or screen is employed. This armature *rotates* between the poles of the magnet U, which are fitted with pole-pieces; the variations in magnetic flux thus obtained give rise to a succession of alternating currents that are utilised for igniting the gaseous mixture. In fact, if contact be suddenly broken between any two conductors traversed by the current, a "break" spark results, and the mixture is ignited. This sudden rupture of continuity is obtained by means of a system of levers, actuated by the engine itself. In motors

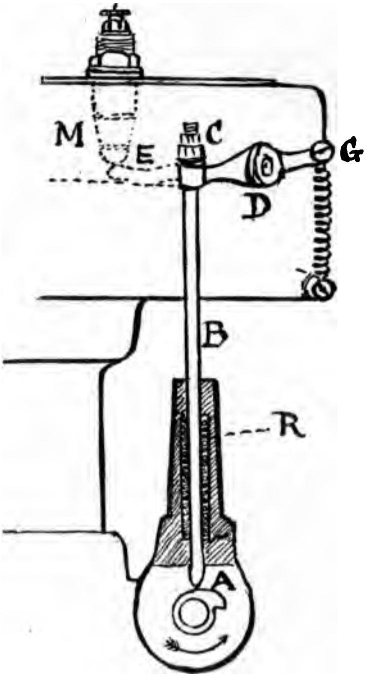

FIG. 35.

of from 18 H.P. to 24 H.P. (see Fig. 35), a cam, A, is keyed or otherwise rigidly fastened to the shaft in the admission, acting upon a tappet rod, B, running in a vertical guide. This tappet terminates above in two regulating nuts, and is kept in contact with the cam A by the spring R. A little two-branched lever, G, is fitted on a crank at D, the axis of the crank itself passing into the interior of the combustion chamber through a suitably plugged aperture in its side. In the interior of the combustion chamber an extension of the lever at E comes into contact with the sparking-plug M, which is made of nickel and of the type shown in our Figs. 15 and 16—*q.v.* On the exterior of the chamber one branch of the lever is kept in position by the counter spring G, while the other end receives the pressure of the push C. As the rod B rests against the circular portion of the cam A, the push C keeps the pieces E and M apart. When this rod is raised by the cam, the nutted end thereof releases the little lever G, and, consequently, the piece E is brought into contact with the sparker M. The current set up by the magneto is led by an insulated cable to the said igniter M, which is likewise insulated. While in this position the circuit is complete through the body of the car or "earth," since the parts E and M are in contact; but, as the cam continues its rotation, on arriving at the depression, it frees the tappet rod B, which suddenly falls to its lowest position under the influence of the spring R; the push, therefore, withdraws the little lever G, producing thereby an interruption in the circuit, and consequently a spark at the igniter.

57. "High" and "Low" Tension Compared.—In conclusion, we may glance at some of the advantages and disadvantages in the high tension and low tension systems. Although makers of late have rather favoured the high tension system under the impression that the high tension current set up by such magnetos is more efficient in producing the ignition of the gaseous mixture, yet, after a considerable experience with many of these appliances, we have come to the conclusion that the difference, if any, is rather in favour of the low tension—for this reason, that ignition is more readily effected by a spark of considerable volume, technically known as a "fat spark," than by one in which the tension is high, but in which quantity is wanting. It is difficult, if not practically impossible, in the confined space admissible in the magneto, to unite quantity and high tension in one and the same instrument, since this would necessitate, on the secondary winding, a large quantity of coarse wire. The flash produced by the low tension magneto is very hot, and this is a great point in its favour. Added to this, we have the advantage that, just in consequence of the, comparatively speaking, low tension of the current employed, the tendency to leakage is not nearly so great, and therefore the probability of breakdowns through defective insulation is minimised. As the voltage in a low-tension magneto rarely exceeds a few hundred volts, while that in one of the high tension class may amount to 25,000 or more, it will be evident that this point is one of very considerable importance in the selection of a machine. Another good point is the facility with which the timing can be regulated if an oscillating shield be employed in conjunction with a low tension armature. The only drawback is the fact that the low tension magneto, as it does not produce a "jump spark," must be fitted with a suitable ignition plug, one similar to those shown in our Figs. 15 and 16, and partaking of similar characteristics, which are those of breaking and making the contact in the interior of the combustion-chamber, effecting this with certainty, and at the desired instant.

THE END

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